SAN JOAQUIN ENERGY CONSULTANTS, INC.

Donna M. Thompson, President **Calif. Reg. Geologist No. 5347; Calif. Cert. Hydrogeologist No. HG 241**

1400 Easton Drive, Suite 133, Bakersfield, CA 93309 (661) 395-3029 FAX: (661) 395-0724

March 7, 2000

Ms. Laura Tom Bose
Groundwater Office of the Environmental Protection Agency Region IX
75 Hawthorne Street
San Francisco, California 94105

Dear Ms. Bose:

SUBJECT: Underground Injection Control (UIC) Permit Application, Elk Hills Power Plant
Permit No. CA200002
Environmental Protection Agency (EPA) Technical Review

The following comments address the need for additional information on the UIC Permit Application for the proposed Elk Hills Power Plant, as discussed in your technical review letter of February 23, 2000, to Mr. Donald E. Romine of Elk Hills Power, LLC. The comments correspond to the items as numbered in the technical review letter.

2. DATA: WELLS WITHIN AREA OF REVIEW

The calculations generally do assume that "the formation characteristics and behavior are uniformly applied across the entire section of the injection zone" because the available data support, and indeed may require, this assumption. The general and site-specific factors that justify this assumption are discussed separately in the following sections.

A) <u>General assumptions for waste front calculations:</u>

The waste front calculation used for this project is a standard, industry-accepted method of determining the area of influence for an injection operation (Warner and Lehr, 1981). The same method also was used to calculate the waste front in a similar Tulare sand injection zone for the permitted, Class I injection wells at the La Paloma Generating Company site (Kennedy/Jenks Consultants, 1999) as well as other permitted, UIC injection projects. In fact, the proposed injection area at the Elk Hills Power site actually appears to be more favorable than the permitted La Paloma site in many aspects, further supporting the use of these waste front calculations. A comparison between the proposed Elk Hills Power Plant and the La Paloma site is shown in the following table.

DESCRIPTION	ELK HILLS POWER	LA PALOMA
Confining zone Formation	Tulare Formation	Tulare Formation
Thickness	~80 ft	≥25 ft
Permeability	44 md	29 md[1]
Injection zone Formation	Tulare Formation	Tulare Formation
Estimated Depth	600 ft to 1,800 ft	350 ft to 1,000 ft
Gross Thickness of Interval	1,200	850
Net Thickness of Sand	750	350
Porosity	34%	33%
Permeability	3,757 md	2,077 to 3,769 md[1]
		Average: 2,923 md[1]
Injectate		
Total dissolved solids (TDS)	1,200 mg/l	3,100 mg/l
Peak discharge rate (bbls/day)	15,000	17,417
Average discharge rate (bbls/day)	12,000	13,028

[1] Although the La Paloma Generating Company Permit Application states that these data are hydraulic conductivities, the data actually appear to be permeabilities to air (Appendix F in Kennedy/Jenks Consultants, 1999). Units of millidarcies (md) are consistent with permeability, whereas units of cm/s typically are used with hydraulic conductivity.

The basic components used for determining the waste front of the proposed injection wells at the Elk Hills Power Project are: the cumulative volume of injectate, the net sand thickness in the injection zone, the porosity of the injection zone, and the dispersion coefficient (UIC Permit Application, Attachment 18). These components and how variations in them affect the area of influence are discussed separately in the following sections.

B) <u>Specific assumptions for waste front calculations</u>

a) Cumulative volume of injectate: In Section 7.B of the UIC Permit Application, the average discharge rate of injectate was estimated to be 503,000 gallons per day (gpd), or 12,000 barrels per day (bpd). The peak discharge rate was estimated to be 628,500 gpd, or 15,000 bpd. The cumulative volume used in the waste front calculation assumed that the peak discharge rate of 15,000 bpd would be injected over the entire 20-year life of the project, resulting in a larger than expected area of influence.

b) Net sand in the injection zone: Net sands were calculated using a standard, industry-accepted technique based on analysis of geophysical well logs and lithology. Shales were identified by correlating lithology and well log response in well 45WS-18G, the closest well to the proposed injection wells (UIC Permit Application, Attachment 2). Baseline resistivities of 1.0 to 1.5 ohm-meters (Ω·m) were determined for clays/shales. A conservative net sand count was calculated using a resistivity cut-off of 2.0 to 2.5 Ω·m. The net thickness of sands in the proposed Tulare injection zone averaged 788 ft. A net sand thickness of 749 ft was used in the waste front calculation, also resulting in a larger than expected area of influence.

c) Porosity in the injection zone: Core data, well logs, and cross-sections presented in the UIC Permit Application indicate a relatively high degree of homogeneity in sands and gravels within the proposed Tulare injection zone. Based on 37 analyses of whole core data in well 46WD-7G, sands and gravels in the proposed injection zone have a porosity range of 30% to 41%, with a standard deviation of only 2.6%. As discussed in Section 5.H.2 of the UIC Permit Application, the arithmetic mean of this data was a porosity of 34%. This porosity then was used in the waste front calculation (Attachment 18 of the UIC Permit Application). The 34% porosity value agrees well with the porosity of 33% derived from analyses of whole cores in Tulare sands from the first test well drilled by La Paloma for its permitted wastewater injection operations (Kennedy-Jenks, 1999).

d) Dispersion coefficient: Based on Warner and Lehr (1981).

e) Nature of injection zone: Warner and Lehr (1981) state that: "In general, wastewater flow in unfractured sand or sandstone aquifers would be expected to more closely agree with theory than flow in fractured reservoirs or in carbonate aquifers with solution permeability." The proposed injection zone for the Elk Hills Power Plant is similar to the type on which the theoretical waste front calculations are based. There is no evidence that the sands in Tulare injection zone are fractured, and the Tulare zone is not a carbonate aquifer with solution permeability. To further test the effects of significant changes in injection zone parameters on the area of influence, sensitivity calculations were done and are discussed in the following section.

f) Sensitivity calculations: Net sand thicknesses and porosities were varied to evaluate the sensitivity of the area of influence to significant changes in these parameters. Attachment A shows that assuming radial flow with dispersion, the combined effects of a peak discharge rate over the entire 20-year life of the project, a porosity decrease to 30%, and a decrease in net sand thickness to 550 ft would increase the area of influence to only an additional 226.5 ft.

Sensitivity calculations assuming semi-radial flow with dispersion also are included in Attachment A. Combining this condition with a peak discharge rate over the entire 20-year life of the project, a porosity of 34%, and a net sand thickness of 750 ft, the area of influence would increase by only 385 ft. If the porosity were decreased to 30% and the net sand thickness reduced to 550 ft, the area of influence based on semi-radial flow with dispersion would increase by an additional 702.5 ft. However, even under this unlikely condition, the area of influence still would be within the limits of the exempt Tulare aquifer. The aquifer exemption for this formation is discussed in more detail under Item 5.G of this letter.

__Conclusion:__ Based on this data, the net height of 750 ft and porosity of 34% used in the waste front calculations represent reasonable, conservative estimates of formation properties at the proposed well locations. The assumption of radial flow also is prudent, reasonable, and consistent with flow assumptions used in similar projects in this injection zone by other operators.

C) __General assumptions for pressure front calculations:__ The assumptions in the pressure front calculations used for the proposed injection wells were discussed by Warner and Lehr (1981):

"The solution first formulated and still most widely used for predicting the pressure effects of a well pumping from or injecting into an aquifer assumes the following conditions…:

1. The aquifer is, for practical purposes, infinite in areal extent
2. The aquifer is homogeneous, isotropic, and of uniform thickness over the area of influence
3. Natural flow is the aquifer is at a negligible rate
4. The aquifer is sufficiently confined so that flow across confining beds is negligible
5. The well penetrates the entire thickness of the aquifer
6. The well is small enough that storage in the well can be neglected and water removed from or placed in storage in the aquifer is discharged or taken in instantaneously, with change in hydraulic head.

"This is a formidable list of assumptions, which are obviously not completely met in any real situation. *However, if one reviews the characteristics of many aquifers used for waste injection, water supply, and other purposes, it can be concluded that for practical purposes they probably comply sufficiently with the assumptions* [italics added]."

The pressure front calculations used in the UIC Permit Application are standard, industry-accepted methods to estimate the rate of pressure change in an injection zone. Kennedy/Jenks Consultants (1999) used the same pressure front calculation method for the injection wells permitted for La Paloma Generating Company.

3.A. Regional Structural Geology

A generalized geologic map of the Elk Hills area is included as Attachment B. A more detailed, regional geologic cross-section is in Figure 8 of *Geology and Geohydrology of the Tulare Formation, 7G/18G Produced Water Disposal Area, South Flank NPR-1*, by Mr. Mark Milliken of the U.S. Department of Energy, December 1992, which was mailed on February 4, 2000. A copy of this map is included as Attachment C.

4. HYDROGEOLOGY OF CONFINING ZONE FOR PROPOSED AND EXISTING WELLS

A) **Tulare clay outcrop area:** The nearest Tulare clay outcrops were mapped by Milliken (1992) as occurring about 2,500 ft north of the proposed injection wells, or about 1,500 ft outside of the area of influence (Attachment D). The sensitivity calculations in preceding Item 2.B.f show that even assuming the combined effects of semi-radial flow with dispersion, peak discharge over the entire 20-year life of the project, porosity reduced to 30%, and net sand thickness decreased by 200 ft, the area of influence in 20 years still will be about 800 ft away from the outcrop of the *top* of the Tulare clay. The base of the Tulare clay confining zone, along which potential seepage would more likely surface, lies an additional 750 ft to the north of this area, or about 1,550 ft outside of a worst-case area of influence.

In addition, the Tulare clay outcrop area lies about 100 ft higher in elevation than the area of the proposed injection wells. This fact gains significance when one considers that this represents about a 44-psi pressure gradient. Since the pressure front at a radius of 1,250 ft gains only 4.6 psi after 20 years (10.6 psi at the wellbore), the injectate would not have the energy to climb the natural pressure gradient, much less surface at the outcrop area.

Both the waste front and pressure front calculations indicate that it is unlikely that the Tulare clay outcrops would have significant impact on the proposed injection wells.

B) **Permeability of Tulare clay:** For purposes of completing the UIC Permit Application, the permeability of the Tulare confining zone was estimated based on analyses of whole core data from clays and siltstones in well 46WD-7G (UIC Permit Application, Attachment 9). The estimated permeability of 44 md represents permeability to air (K_a), as determined from analyses of dry samples heated to about 235°F. Aquifers that contain clay minerals, such as the Tulare aquifer, probably have lower permeability to water than to air (Warner and Lehr, 1981). When saturated, the permeabilities of clays and siltstones typically are reduced to less than 1 md.

The permeability of the Tulare clay confining layer is expected to be significantly lower and will be confirmed by analysis of core samples collected while drilling the proposed injection wells.

C) <u>Confining ability of the Tulare clay:</u> Site-specific analysis using local well data was discussed in the UIC Permit Application. In addition, Milliken (1992) analyzed groundwater quality using resistivity data above, within, and below the Tulare injection zone in two wells located about 1.5 miles southwest of the proposed injection area. Milliken concluded that both "...the Tulare and Amnicola clays separate aquifers of greatly different water qualities, and underscore this report's conclusion that the Tulare Formation clays are barriers to groundwater movement across beds." The ability of the Tulare clay to act as an effective confining zone is based not only on the typical behavior of saturated clays to act as barriers to groundwater movement but on documented differences in groundwater quality above and below it.

5.G. Description of vertical and lateral continuity of injection zone within a minimum one-mile radius of the proposed injection wells

A) <u>One-mile area of review:</u> A one-mile radius of review does not appear to be justified based on sensitivity calculations discussed in Item 2.B.f of this letter. Even assuming the combined effects of semi-radial flow with dispersion, peak discharge over the entire 20-year life of the project, porosity reduced to 30%, and net sand thickness decreased by 200 ft, the area of influence is 1,696.5 ft in 20 years. This unlikely scenario still is well within the current 0.5-mile, or 2,640-ft, area of review.

B) <u>Outcrop of Tulare injection zone:</u> The outcrop of the Tulare injection zone was mapped by Milliken (1992) and is included as Attachment D. The Tulare injection zone crops out northward of the base of the unit mapped as "tc_3". This outcrop is located about 3,300 ft north of the proposed injection wells, or about 2,300 ft outside of the area of influence. Based on the sensitivity calculations discussed in preceding Item 2.B.f, it is unlikely that the waste front would reach the outcrop area. Also, the area where the Tulare injection zone crops out is about 100 ft higher in elevation than the area of the proposed injection wells, and injection pressures are well below those required to surface at the outcrops. As discussed in Item 4.A of this letter, neither the waste front nor the pressure front calculations indicate that the injectate would reach the outcrop area. Finally, saturated Tulare clay has been documented as a groundwater barrier in the Elk Hills area (Milliken, 1992; Phillips, 1992; Milliken, 1993) and is expected to act as such in the area of the proposed injection wells.

C) **Overlying aquifer:** As provided in the UIC Permit Application, groundwater data in the proposed injection area suggest that the Tulare clay confining zone provides hydrogeologic separation between the Tulare injection zone and the overlying alluvial aquifer. Resistivity contrasts are apparent in the cross-sections included in Attachment 8 of the UIC Permit Application[2]. Resistivities within the proposed Tulare injection zone appear to be higher than in the intervals above the Tulare clay and below the Amnicola clay. This relationship suggests that groundwater in the proposed Tulare injection zone has lower salinity than that which underlies and overlies it. As such, it indicates the ability of the Tulare and Amnicola clays to act as groundwater barriers for the proposed injection interval.

The nature of the alluvial aquifer and its relation to the Tulare Formation also were the subject of several reports in which the authors independently reached similar conclusions. Based on analyses of well data, geophysical logs, and groundwater quality data, Bean and Logan (1983), WZI (1988), and Milliken (1992) all concluded that the Tulare clay forms a barrier to groundwater migration between the Tulare Formation and the overlying alluvium. Milliken (1992) further stated that: "...the 7G/18G disposal wells are hydrogeologically isolated from the alluvium by clay beds of not only the Tulare clay, but numerous other clays above and below the Tulare clay interval." Milliken (1992) concluded that: "The alluvium of the Buena Vista Valley, from which agricultural water production is obtained, is geohydrologically isolated from the Tulare Formation disposal wells and is in no immediate danger of contamination."

Milliken's analyses of groundwater quality in the alluvial aquifer using resistivity data "...suggested relatively poor water quality above the Tulare clay" (1992). Because the groundwater quality below the Tulare clay in the proposed injection zone averaged 4,500 to 6,100 mg/l TDS, the overlying alluvial aquifer probably has higher TDS concentrations. That the overlying alluvial aquifer is an underground source of drinking water (USDW) merely is assumed at this point. Groundwater data will be collected during drilling the proposed injection wells to evaluate whether there is an overlying aquifer and if it qualifies as an USDW.

D) **Tulare aquifer exemption:** It should be noted that the proposed and existing injection wells use the exempt Tulare aquifer. The Tulare aquifer was exempted by the California Division of Oil, Gas, and Geothermal Resources as an USDW based on petroleum production within the administrative limits of the Elk Hills oil and gas field. Groundwater in the Tulare aquifer also has TDS concentrations in excess of 3,000 mg/l and does not or is not reasonably expected in the future to serve as an USDW. Approved well construction

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[2] Resistivity curves are shown on the right side of well logs in cross-sections in Attachment 8 of the UIC Permit Application.

and mechanical integrity testing of the proposed injection wells will further ensure that the injectate will be disposed into the permitted zone and not overlying aquifers.

5.H.7. Formation Fracture Pressure

Attachment E is the California Division of Oil, Gas, and Geothermal Resources permit conditions for operating the Class II produced water disposal wells located in the Tulare formation about 0.75 miles north of the proposed disposal wells. The approval letter, dated January 6, 1999, specified an allowable injection gradient of 0.8 psi/ft. This gradient is based on step-rate tests done on a number of Tulare SWD wells in the early 1990s.

7.D Detailed description of sampling and analytical methods, including quality assurance/quality control (QA/QC) procedures

This information will be submitted under separate cover.

8. AREA OF REVIEW

As discussed in preceding Item 2.B.f, Attachment A shows the sensitivity analyses for variables used in the waste front calculations, including scenarios for semi-radial flow. These calculations show that after 20 years of injection the waste fronts will not reach the identified outcrops located updip and about 3,000 ft north of the proposed wells, even if formation porosity and net sand thickness is significantly worse that what was assumed in the baseline calculations. The available data support the use of a radial flow model, and extensive review did not reveal data supporting the use of a non-radial flow model. Injected water should flow toward pressure sinks, which generally will be located downgradient of the injection point and/or away from pressure fronts manifested by existing SWD wells upgradient of the proposed injection wells. These factors suggest that any non-radial flow that may occur would be away from the identified outcrops.

11.B. Schematic Diagrams

The requirement to plug the wells from bottom to top with cement complicates the abandonment procedure, doubles abandonment costs, and does not significantly improve groundwater safety. The proposed abandonment plan conforms to DOGGR plugging and abandonment requirements for Class II injection wells, which inject fluids with significantly higher concentrations of contaminants than the proposed injection wells.

12.F.8 (Freshwater Baseline)

A copy of the Phillips (1992) reference will be provided under separate cover.

13.A Injection Rate (Volume)

Barton recorders or SCADA devices shall be installed to provide continuous monitoring of injection rates and pressure and annulus pressure.

13.B. Injection pressure

Previous discussion and documentation demonstrate a fracture pressure in excess of 0.8 psi/ft. Step-rate tests will be done on the proposed injection wells to confirm earlier data.

16.A. Financial Assurance

A cost estimate has been completed and will be provided under separate cover.

California Unions for Reliable Energy (CURE)

In their letter of November 16, 1999, Messrs. Jeff Bachhuber and Charles M. Brankman of William Lettice & Associates, Inc., (WLA) addressed several comments on the proposed EHPP to Ms. Lizanne Reynolds representing CURE. Comments on the WLA letter are addressed in Attachment F, which includes an independent geologic opinion on the features mapped as surface faults by WLA.

Please call if you have any questions.

Sincerely,

Donna M. Thompson

Donna M. Thompson

Barry Hanson

Barry Hanson

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Enclosures

cc: Mr. Dennis Champion, Elk Hills Power, LLC
Mr. George Robin, EPA
Mr. Taylor Miller, Downey, Brand, Seymour & Rohwer, LLP
Mr. Terry Schroepfer, Quad Knopf

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Net Height & Porosity Sensitivity: Radial Flow
20 Year Radius (with dispersion) @ 15,000 BWIPD

Net H \ Porosity	0.38	**0.34**	0.30
950	844.4	889.5	943.3
750	943.3	**993.9**	1054.3
550	1091.6	1150.4	1220.5

Net Height & Porosity Sensitivity: Semi-Radial Flow
20 Year Radius (with dispersion) @ 15,000 BWIPD

Net H \ Porosity	0.38	**0.34**	0.30
950	1169.8	1233.0	1308.3
750	1308.3	**1379.1**	1463.6
550	1515.8	1598.2	1696.5

GEOLOGIC MAP OF THE 7G/18G PW DISPOSAL AREA, SOUTH FLANK NPR-1

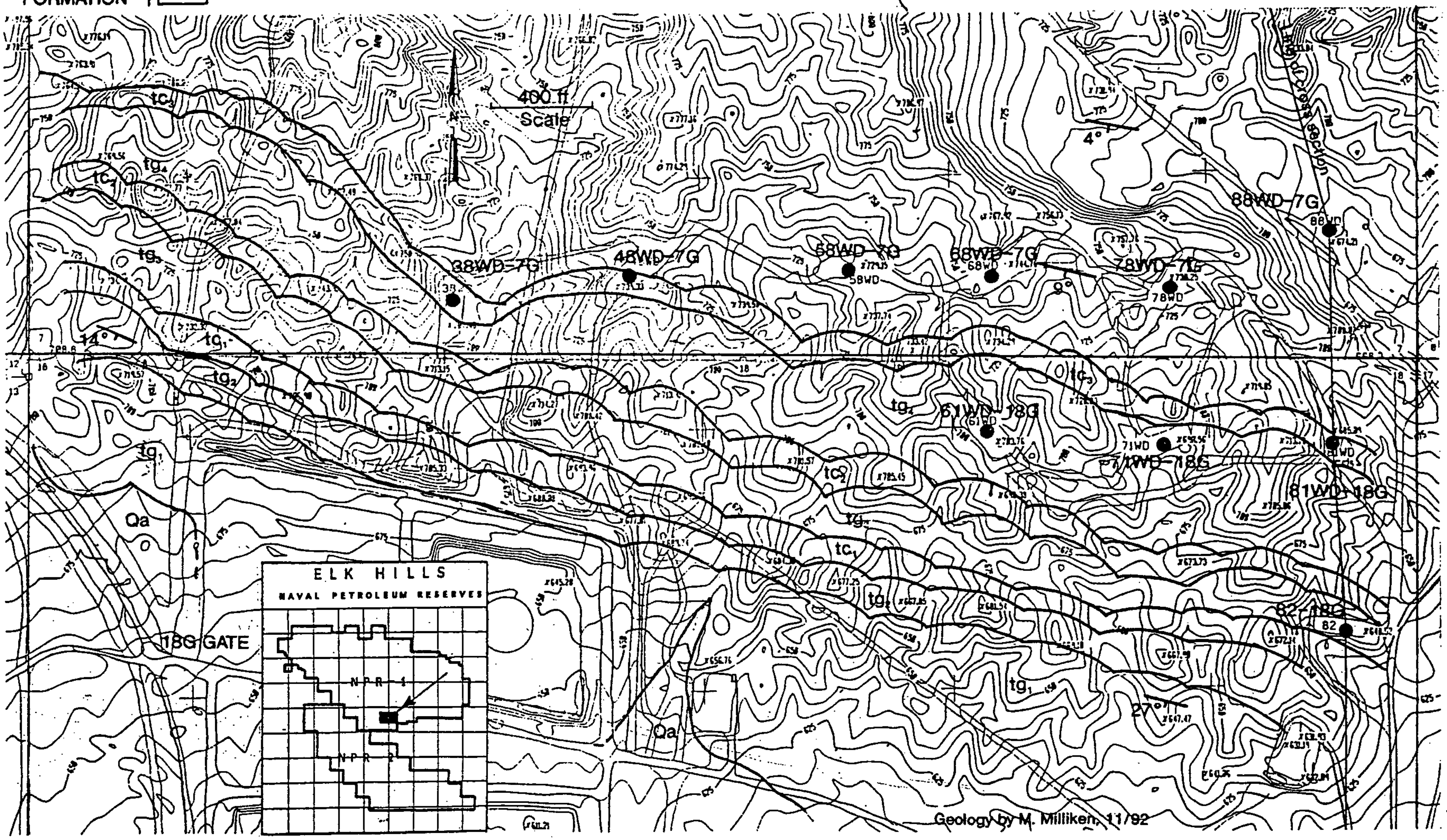
Figure 6.

ROCKS OF THE TULARE FORMATION

Qa	Alluvium, mostly reworked Tulare Formation, post-dates Elk Hills uplift.
tg_1	Gravel, silty, buff color, clasts primarily siliceous shale.
tg_2	Gravel, sandy, cg–vcg sand, gray, igneous/metamorphic clasts to 5" dia.

TULARE CLAY

tc_1	Clay, silty, buff.
tg_3	Gravel, sandy, gray.
tc_2	Clay, silty, minor sand, buff.
tg_4	Gravel, sandy, gray. A 5' sandy silt is 6' above the base.
tc_3	Clay, silty, buff.



ATTACHMENT B

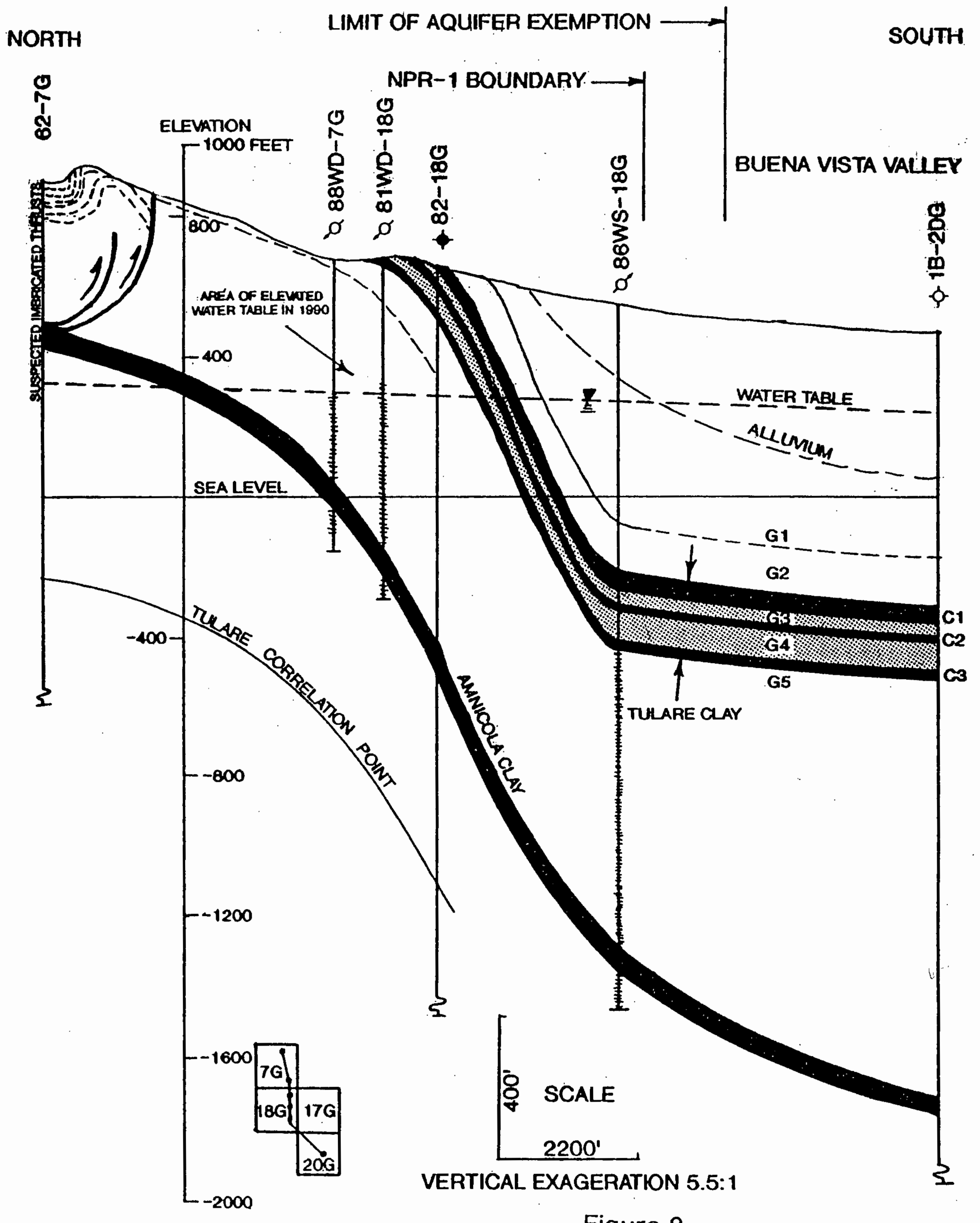
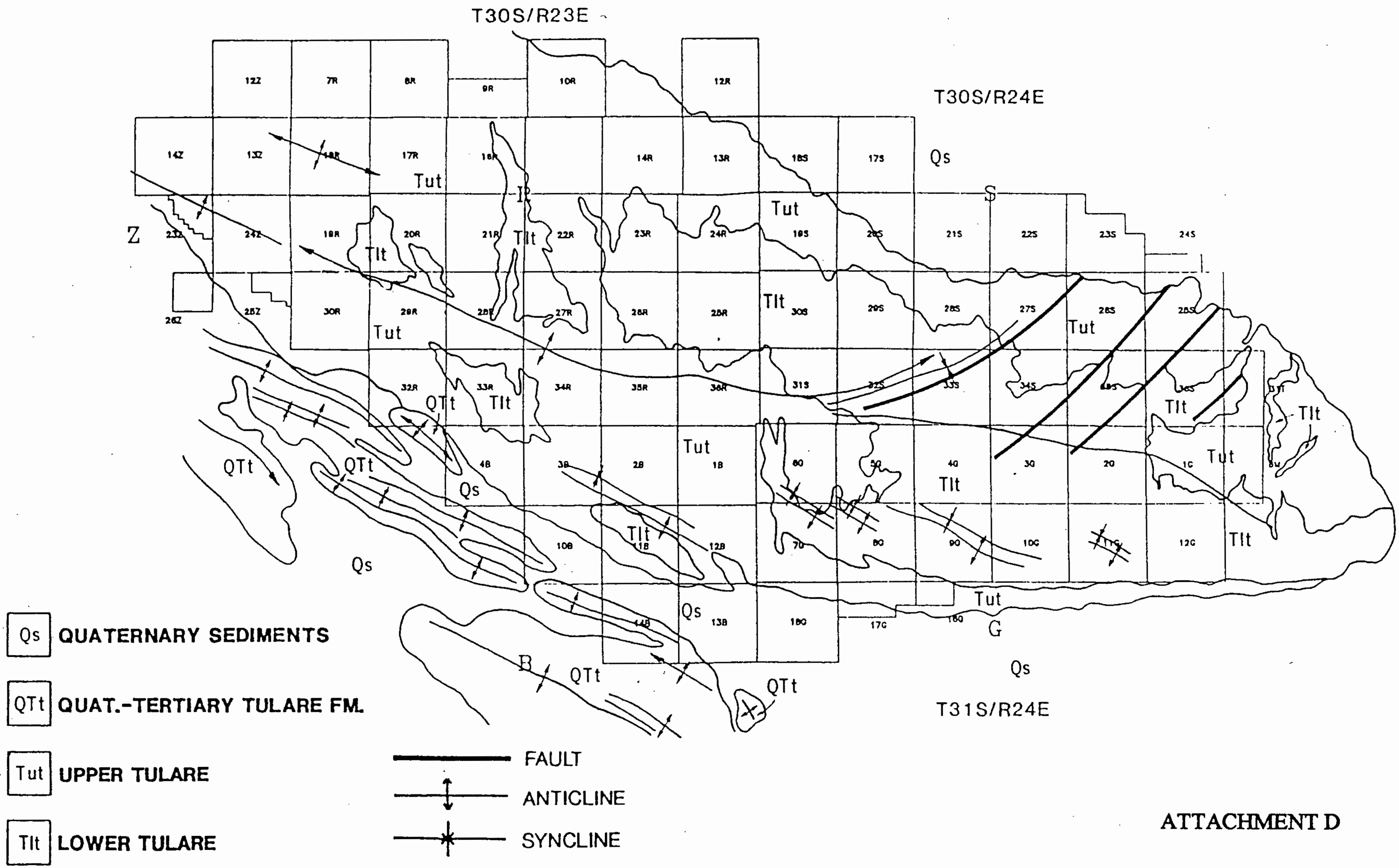


Figure 8.
STRUCTURAL CROSS SECTION
SOUTH FLANK NPR-1 TO BUENA VISTA VALLEY

ATTACHMENT C

Figure 1.3 GENERALIZED GEOLOGIC MAP OF ELK HILLS



ATTACHMENT D

Modified from: WOODRING, 1932 and MAHER, 1975

STATE OF CALIFORNIA—THE RESOURCES AGENCY GRAY DAVIS, Governor

DEPARTMENT OF CONSERVATION

4800 STOCKDALE HWY, SUITE 417
BAKERSFIELD, CALIFORNIA 93309
(805) 322-4031
FAX: (805) 861-0279

January 6, 1999

corrected copy

Mr. Robert D. Hunt
Occidental of Elk Hills, Inc.
P.O. Box 1001
Tupman, CA 93276

WATER DISPOSAL PROJECT
Elk Hills Field
Tulare Zone
Sec. 18, T.31S., R.24E

Project Code: 22800002
Max. Permitted Volume: 180000 B/D
Max. Permitted Well(s): 21
Note: Notify this office if either of these values are exceeded.

Dear Mr. Hunt:

The expansion of the project designated above is approved provided:

1. Notices of intention to drill, redrill, deepen, rework, or abandon, on current Division forms (OG105, OG107, OG108) shall be completed and submitted to the Division for approval whenever a new well is to be drilled for use as an injection well and whenever an existing well is converted to an injection well, even if no work is required on the well.

2. This office shall be notified of any anticipated changes in a project resulting in alteration of conditions originally approved, such as: increase in size, change of injection interval, or increase in injection pressures. Such changes shall not be carried out without Division approval.

3. A monthly Injection Report shall be filed with this Division on our Form OG110B on or before the last day of each month, for the preceding month, showing the amount of fluid injected, and surface pressure required for each injection well.

4. A chemical analysis of the fluid to be injected shall be made and filed with this Division whenever the source of injection fluid is changed, or as requested by this office. ALL FLUIDS MUST MEET CLASS II CRITERIA.

5. All fluid sampling and analyses required by this Division are done in accordance with the provisions of the Division's Quality Assurance Program. Please refer to the Division's "Notice to Oil and Gas Operators" dated: November 17, 1986.

6. An accurate, operating pressure gauge or pressure recording device shall be available at all times, and all injection wells shall be equipped for installation and operation of such gauge or device. A gauge or device used for injection pressure testing, which is permanently affixed to the well or any part of the injection system, shall be calibrated at least every six months. Portable gauges shall be calibrated at least every two months. Evidence of such calibration shall be available to the Division upon request.

7. All injection wells shall be equipped with tubing and packer set immediately above the approved zone of injection upon completion or recompletion, unless a variance to this requirement has been granted by this office.

8. A Standard Annular Pressure Test (SAPT) shall be run, as outlined in the Notice to Operators dated 1/9/90, prior to injecting into any well(s) being drilled or reworked for the purpose of injection and every five years thereafter or as requested by the Division. The Division shall be notified to witness such tests.

9. Injection profile surveys for all fluid injection wells shall be filed with the Division within three (3) months after injection has commenced, once every year thereafter, after any significant anomalous rate or pressure change, or as requested by the Division, to confirm that the injection fluid is confined to the proper zone or zones. This monitoring schedule may be modified by the district deputy. This office shall be notified before such surveys are made, as surveys may be witnessed by the Division inspector.

10. Data shall be maintained to show performance of the project and to establish that no damage to life, health, property, or natural resources is occurring by reason of the project. Injection shall be stopped if there is evidence of such damage, of loss of hydrocarbons, or upon written notice from the Division. Project data shall be available for periodic inspection by Division personnel.

11. The maximum allowable injection pressure gradient is limited to .8 psi per foot of depth as measured at the top perforation. Prior to any sustained injection above this gradient, rate-pressure tests shall be made. The test shall begin at the hydrostatic gradient of the injection fluid to be used and shall continue until either the intended maximum injection pressure is reached or until the formation fractures, whichever occurs first. These tests tests shall be witnessed, unless otherwise instructed, and the test results submitted to this Division for approval.

12. All injection piping, valves, and facilities shall meet or exceed design standards for the injection pressure and shall be maintained in a safe and leak-free condition.

13. Any remedial work needed as a result of this project on idle, abandoned, or deeper zone wells in order to protect oil, gas, or freshwater zones, shall be the responsibility of the project operator.

14. Additional data will be supplied upon the request of the Division.

Sincerely,

Hal Bopp
Deputy Supervisor
Division of Oil, Gas, and Geothermal Resources

cc: RWQCB
UIC file

uic\wp\wd

ATTACHMENT A

TESTIMONY OF DONNA M. THOMPSON REGARDING PROPOSED CLASS I INJECTION WELLS IN SUPPORT OF THE APPLICATION FOR CERTIFICATION FOR THE ELK HILLS POWER PROJECT

This testimony will offer the California Energy Commission ("Commission") details on the potential impacts of the Elk Hills Power Project (EHPP) on groundwater resources. The purpose of this testimony is to demonstrate that:

- EHPP will be designed and operated in compliance with applicable LORS,
- construction and operation of EHPP including the proposed mitigation measures will not cause any significant adverse environmental impacts, and
- EHPP will be constructed and operated to protect the health and safety of EHPP employees, contractors and the general public.

I. Project Description

The EHPP consists of a nominal 500-MW natural gas-fired power plant, transmission line, natural gas pipeline, and water supply and wastewater disposal pipelines. The proposed power plant site is located near the center of the Elk Hills oil and gas field. Wastewater produced by the plant will be conveyed by a new 4.4 mile, 6-inch pipeline to new disposal wells to be located about 4 miles south of the power plant site.

II. Affected Environment

Wastewater from the EHPP will be injected into two proposed underground injection wells, located about four miles south of the power plant site in the southwest quarter of Section 18, Township 31 South, Range 24 East, Mount Diablo Base & Meridian. The proposed injection zone is in the Tulare Formation at depths between about 600 ft and 1,800 ft. Above the proposed Tulare injection zone, the Tulare clay appears as a laterally and vertically continuous confining zone. The area of influence for the proposed injection wells is the distance that injected fluid is predicted to travel based on the volume of injectate and the net thickness and effective porosity of the receiving zone. The area of influence was calculated to be about 1,000 feet from the proposed injection wells.

III. Compliance with Applicable LORS

As briefly demonstrated below, EHPP will comply with applicable Laws Ordinances Regulations and Standards (LORS) regarding the two proposed Class I injection wells.

The construction and soundness of the two proposed Class I injection wells will be approved by the Environmental Protection Agency under the Federal Underground Injection Control program. Waste discharge requirements and fees will be determined by the California Regional Water Quality Control Board. Well drilling and construction will be approved by the Division of Oil, Gas, and Geothermal Resources.

IV. Potential Environmental Benefits and Impacts

Operational Impacts

The proposed wastewater injection operations will affect groundwater within the Tulare injection zone. However, the Tulare Formation is exempted by the Division of Oil, Gas, and Geothermal Resources as an underground source of drinking water within the boundaries of the Elk Hills and Midway-Sunset oil fields based on petroleum production. Groundwater does not serve as an underground source of drinking water and is not reasonably expected to serve as one in the future. In the proposed Tulare injection zone, groundwater has total dissolved solids (TDS) greater than 3,000 mg/l and less than 10,000 mg/l and high concentrations of chloride and boron. The proposed injectate is expected to have a TDS concentration of about 1,200 mg/l.

A. Cumulative Impacts

Construction and operation of the EHPP have very little potential for cumulative impacts to groundwater resources beneath the Elk Hills oil and gas field. Groundwater at the power plant site is more than 1,000 feet beneath ground surface and has no beneficial use. Deep well injection of project wastewater will be in the exempt, high TDS Tulare aquifer. No cumulative impacts are expected from wastewater disposal.

V. Comments on William Lettis Associates (WLA) Letter of November 16, 1999

Messrs. Jeff Bachhuber and Charles M. Brankman of William Lettice & Associates, Inc., (WLA) addressed several comments on the proposed EHPP to Ms. Lizanne Reynolds in a letter dated November 16, 1999. Comments on the WLA letter are addressed in the following paragraphs.

1. WLA concern: Site-specific geologic, subsurface, and hydrogeologic investigations have not adequately characterized the injection field (WLA Item 1 of "Specific Issues").

   Response: The nearest subsurface well data are within about 400 ft of the proposed disposal wells. Five wells within the area of review and at least 40 other wells with subsurface data were reviewed for constructing cross-sections and maps in the Class I injection well permit application to the Environmental Protection Agency, titled *Information Needs for Class V Injection Wells, Elk Hills Power Plant*, dated

September 21, 1999. Lithologic and geophysical well log information from these wells was used in analysis of the proposed injection area. In addition, site studies were done by Milliken (1992) and Phillips (1992) to evaluate the local surface and subsurface geology, hydrogeology, and groundwater quality in the Section 7, Township 31 South, Range 24 East, Mount Diablo Base & Meridian, (7G) and 18G area.

2. WLA concern: The local heterogeneity in the stratigraphy and clay composition of the Tulare clay argues against the use of regional or off-site data to evaluate possible impacts from the proposed injection wells (WLA Item 1a of "Specific Issues").

   Response: The Tulare clay outcrops referenced in Milliken (1992) occur about 2,500 ft north of the proposed injection wells, which is about 1,500 outside of the area of influence. Although the Tulare clay in the outcrop area has interbedded sand and gravel layers, it also has thick clay layers, ranging to a thickness of about 40 ft (Milliken, 1992). Closer to the proposed injection wells, a thick clay layer in the confining zone is indicated by lithologic and geophysical well data from well 45WS-18G, which lies only about 400 ft to the southwest. Based on correlations of the lithologic and log characteristics of the Tulare clay within the area of influence, the Tulare clay appears to consist mainly of clay. Interbedded sands and gravels do not appear to be a significant component of the Tulare clay within the area of proposed injection operations.

3. WLA concern: The proposed injection wells rely solely on the integrity of the Tulare clay, and additional data are necessary to verify the continuity and low permeability of the Tulare clay layer near the proposed injection wells (WLA Item 1b of "Specific Issues").

   Response: In addition to site-specific analysis using local well control, as provided in the Class I injection well permit application to the Environmental Protection Agency of September 21, 1999, Milliken (1992) analyzed groundwater quality and resistivity data above and below the Tulare injection interval in two wells located about 1.5 miles southwest of the proposed injection area. Milliken concluded that both "...the [overlying] Tulare and [underlying] Amnicola clays separate aquifers of greatly different water qualities, and underscore this report's conclusion that the Tulare Formation clays are barriers to groundwater movement across beds."

4. WLA concern: Qualitative and quantitative field and laboratory analyses have not been performed on borehole or outcrop samples of the Tulare clay to define mechanical and permeability/transmissivity properties (WLA Item 2 of "Specific Issues").

   Response: Outcrop samples are located about 2,500 ft north of the proposed injection area and probably do not represent the lithology expected in the proposed wells. During drilling the proposed injection wells, samples from the Tulare confining zones and injection intervals will be collected and analyzed for mechanical and permeability/transmissivity properties.

5. WLA concern: Subsurface data from existing wells in the oil field are extrapolated over 2,000 ft in map plan view without local control points at the proposed injection area (WLA Item 3 of "Specific Issues").

   This statement is incorrect. Well 45WS-18G lies about 400 ft northeast of the proposed injection area and was used in the analysis for the Class I injection well permit application to the Environmental Protection Agency, dated September 21, 1999.

6. WLA concern: An apparent east-west trending fault in the Tulare Formation and younger alluvial fans was observed along the base of Elk Hills immediately north of the proposed injection wells and should be inspected in the field. (WLA Item 4a and 4b of "Specific Issues").

   Response: Messrs. Bachhuber and Brankman based their interpretation of surface faulting on 1991 aerial photographs at a scale of 1:24,000, or 1 inch equals 2,000 feet. Four days of field reconnaissance, examination of stereographic pairs of aerial photographs from 1975 and 1981 (scales of 1:12,000, or 1 inch equals 1,000 feet, and 1:24,000, respectively), review of geologic reports (Milliken, 1992; Phillips, 1992) and geologic maps (Dibblee, 1971; Kern County Council of Governments, 1974; Smith, 1965) by San Joaquin Energy Consultants did not support the interpretation of surface features mapped by WLA as being faults. The features mapped as faults by WLA occurred along natural depositional contacts between different lithologies and/or linear cultural features, such as dirt roads, pipelines, or utility lines.

   Surface mapping is a much more reliable method of determining the presence of surface faults than review of aerial photographs. Detailed geologic mapping of the area immediately north of the proposed injection wells was done by Milliken in 1992. No surface faults were mapped by Milliken (1992) in the area where WLA indicated three faults using aerial photographs. In addition, the Taft quadrangle of the Kern County Council of Governments Seismic Hazard Atlas (1974), the Geologic Map of California, Bakersfield Sheet, (Smith, 1974), and Dibblee (1971) show no surface faults in the proposed injection area.

   For an impartial opinion of the surface features mapped as faults by WLA, Mr. Tom Gutcher, an independent, California-registered geologist was asked to evaluate these features using field reconnaissance, aerial photographs, and review of geologic literature. Mr. Gutcher's report about WLA's surface faults, with his detailed geologic analysis of WLA comments, is included as Attachment B. Based on his observations during two days of field work in the area, examination of stereographic pairs of 1975 aerial photographs (scale of 1:12,000), and review of geologic reports (Milliken, 1992; Phillips, 1992) and geologic maps (Dibblee, 1971; Kern County Council of Governments, 1974; Smith, 1965), Mr. Gutcher reached the same conclusion as San Joaquin Energy Consultants, which was that there was no observed evidence of surface faults as mapped by WLA in its Figure 1.

WLA referred to "south-vergent" thrusts in the vicinity of the injection well site on AFC Figure 5.4.5. The features referred to by WLA probably are the north-dipping faults located more than 6,000 ft from the proposed injection wells, or 5,000 ft north of the area of influence. Milliken (1992) refers to these features as "...an interesting fold in the Tulare Formation that is <u>arguably</u> bounded on the south by a normal fault or high angle reverse fault [underline added]." Milliken then offered an alternate, "no fault" explanation that these features represent an unconformity, or erosional surface. Because the features occur rather far north of the area of interest, Milliken did not map this area with the detail given to the 7G/18G study area farther to the south. Milliken (1992) summarized his findings: "Based on limited field mapping, the fold has no impact on the study area. No evidence for faulting was observed within the study area."

7. WLA concern: Based on Milliken's (1993) statement, "...faults in the Tulare Clay have profound effects on groundwater distribution at Elk Hills", WLA said that the influence of faults and fractures in the Tulare clay as potential groundwater barriers or migration paths had not been established and required further characterization. (WLA Item 4c of "Specific Issues").

   Response: WLA refers to Milliken's 1993 report on the geology of the Tupman area, which is located about 3.5 miles from the proposed injection wells and far removed from the area of influence of the proposed injection operations. WLA misquotes Milliken (1993), who actually stated, "...faults in the Tulare have profound effects on groundwater distribution at Elk Hills". Milliken's discussion in the paper regards the entire Tulare Formation and the effects of numerous clays within the unit upon groundwater distribution rather than only the Tulare clay confining zone.

   The faults in the Tupman area generally act as barriers to groundwater movement. Milliken (1993) reports that: "Faults 2 and 3 of Woodring and others (1932) clearly form groundwater barriers" and "Based on comparative data from 35S, other faults in the study area (including the Tupman Fault) may be groundwater barriers as well" (page 30). Milliken (1993) concludes that: "The [Tulare] clays are very clean and are barriers to the vertical migration of groundwater (Bean and Logan, 1983). As uplift of Elk Hills continued in a broad fold, groundwater migration was restricted across dipping beds, leaving water "stranded" high on the structure" (page 31) and "Faults appear to act as barriers to lateral groundwater movement and may be in part responsible for a groundwater mound along the crest of the Elk Hills anticlinal structure" (page 3).

8. WLA concern: The "south margin fault", "thrust faults" shown in AFC Figure 5.4.5, "Boundary Blind Thrusts" within five miles of the site, and/or other potentially active thrust or buried faults could pose a surface fault rupture or earthquake hazard to the disposal wells or pipeline (WLA Item 5a of "Specific Issues").

The Elk Hills oil and gas field was discovered in 1911 and has produced over one billion barrels of oil since that time. Numerous wells and pipelines in the field have not experienced surface fault rupture or earthquake hazard associated with the producing and disposal operations. Lack of evidence for the "south margin fault" and "thrust faults" shown in AFC Figure 5.4.5 was discussed in Item 6 of this section.

9. WLA concern: Wastewater injection could cause creep or displacement along the "south margin fault" or buried thrust faults, shearing injection well casings or affecting the integrity of the Tulare clay (WLA Item 5b of "Specific Issues").

   The Buena Vista Hills Thrust Fault has had historic creep that caused shearing in existing wells, but according to the Taft Sheet of the Seismic Hazard Atlas (1974), it lies about 4.5 miles south of the proposed injection area. No such shearing in wells is known to have occurred in the Elk Hills area. In addition, a search of the National Earthquake Information Center (NEIC) earthquake database indicated that no earthquakes larger than magnitude 1.0 have occurred within the active 7G/18G injection area or the proposed 18G injection area. The NEIC California earthquake database ranges from 1735 to present. The search area included the active injection well field, which has operated from 1981 to present. Although the active injection well field lies within about 800 ft of a feature mapped as a fault by WLA, no seismicity above magnitude 1.0 appears to be associated with its operations.

   Lack of evidence for the "south margin fault" and "thrust faults" shown in AFC Figure 5.4.5 was discussed in Item 6 of this section.

10. WLA concern: Results from geochemical testing are insufficient to argue that existing and past injection operations have not impacted groundwater quality. WLA used "referenced transmissivity values" of between "50 and 700 feet per year" to determine that a time lag of 6 to 80 years would be required before contaminants would migrate to the test wells and that a sufficient amount of time has not passed for the waste front to reach the test wells. (WLA Item 6 and 6b of "Specific Issues").

    Response: It is unclear where WLA derived the "referenced transmissivity values", since no reference is provided and units of feet per year are not used for transmissivity.

    WLA stated that geochemical testing extended for a ten-year time span since initiation of the oil field injection program. This ten-year time period is within the 6- to 80-year range calculated by WLA for the waste front to reach the "test wells". Injection operations began about 19 years ago in 1981.

    It should be noted that the proposed and existing injection wells use the exempt Tulare aquifer. The Tulare aquifer was exempted by the California Division of Oil, Gas, and Geothermal Resources as an underground source of drinking water based on petroleum production within the administrative limits of the Elk Hills oil and gas field. Groundwater in the Tulare aquifer also has TDS concentrations in excess of 3,000 mg/l and does not or is not reasonably expected in the future to serve as an underground source of drinking water. Approved well construction and mechanical integrity testing of the proposed injection wells will further ensure that the injectate will be disposed into the permitted zone and not overlying aquifers.

11. WLA concern: No groundwater data were provided from the overlying alluvial aquifer, which are necessary to show that past and existing injection operations have not impacted water quality (WLA Item 6a of "Specific Issues").

    Response: Groundwater data from the overlying alluvial aquifer in the area were provided as part of the Class I permit application, dated September 21, 1999. These data suggest that the Tulare clay confining zone provides hydrogeologic separation between the Tulare injection zone and the overlying alluvial aquifer. In addition, the nature of the alluvial aquifer and its relation to the Tulare Formation were the subject of several reports in which the authors independently reached similar conclusions. Based on analyses of well data, geophysical logs, and groundwater quality data, Bean and Logan (1983), WZI (1988), and Milliken (1992) all concluded that the Tulare clay forms a barrier to groundwater migration between the Tulare Formation and the overlying alluvium. Milliken (1992) stated further that: "...the 7G/18G disposal wells are hydrogeologically isolated from the alluvium by clay beds of not only the Tulare clay, but numerous other clays above and below the Tulare clay interval." Also, analyses of the groundwater quality of the alluvial aquifer by Milliken (1992) "...suggest relatively poor water quality above the Tulare clay." The groundwater quality below the Tulare clay averaged 4,500 to 6,100 mg/l TDS, suggesting that the overlying alluvial aquifer would have higher TDS concentrations.

VI. Mitigation Measures

Injection well design incorporates redundant containment barriers and surveillance systems to ensure that the injected fluid is confined to the permitted disposal zone throughout the well's service life. Three artificial flow barriers are built into the well design. These include the outermost, cemented steel casing; an interior string of casing completely cemented to the borehole; and the injection tubing and packer. "Packer fluid" with chemicals to prevent corrosion and biological activity is used in the annulus between the tubing and the casing.

Two natural flow barriers ensure fluid containment. The Tulare clay interval above the injection zone and the Amnicola clay interval below it are natural groundwater flow barriers that prevent injected fluid from migrating out of the permitted zone.

Operation of the disposal wells incorporates a surveillance program designed to provide prompt detection and response to any mechanical integrity failures. Key features of the surveillance program are as follows:

- Daily inspection of surface injection lines and equipment to ensure proper operation and to detect and fix any leaks that may develop;

- Daily monitoring of the pressure gauges on the tubing and casing annulus of disposal wells; and
- Annual injection tracer surveys and positive pressure tests to ensure that injection is confined to the permitted zone and to identify any failures that may have occurred in any of the redundant flow barriers.

VII. Conclusions

- The proposed injection wells will inject into an aquifer exempted by the California Division of Oil, Gas, and Geothermal Resources as an underground source of drinking water within the Elk Hills oil and gas field based on petroleum production. Groundwater in the Tulare aquifer also has TDS concentrations in excess of 3,000 mg/l and does not or is not reasonably expected in the future to serve as an underground source of drinking water.
- The groundwater in the proposed injection zone appears to be of better quality than in the overlying alluvial aquifer, and both are poorer in quality than the proposed injectate from Elk Hills Power operations in terms of TDS content.
- The proposed injection well design incorporates redundant containment barriers and surveillance systems to ensure the injectate is confined to the permitted disposal zone throughout the well's service life.
- The Tulare clay above the proposed injection zone and the Amnicola clay below it appear to act as barriers to groundwater flow.
- Evidence of the "south margin fault" and other surface faults mapped by WLA from aerial photographs was not observed in the field by San Joaquin Energy Consultants or an independent, California-registered geologist.
- There are sufficient data to characterize the geology and hydrogeology of the proposed injection area.
- Construction and operation of the EHPP have little potential for significant impacts to groundwater resources beneath the Elk Hills oil and gas field.
- I have reviewed CEC Staff's analysis and conclusions regarding Water Resources contained in the Final Staff Assessment (FSA) for the EHPP. I support CEC Staff's conclusions. Staff did not complete its analysis of the project's conformity with potential impacts from operation of wastewater injection wells. Therefore, I reserve the right to review and comment on Staff's Supplemental Testimony on these issues when they become available.

SMITH - GUTCHER
AND ASSOCIATES, INC.
Consulting Geologists
Post Office Box 60706
Bakersfield, California 93386-0706
(661) 871-3207 FAX (661) 871-3698

February 25, 2000

Donna Thompson
San Joaquin Energy Consultants, Inc.
1400 Easton Drive, Suite 133
Bakersfield, California 93309

Subject: Possible Surface Faults in the Vicinity of the Proposed Class I Injection Wells, Elk Hills Power Plant, Elk Hills Oil and Gas Field, Kern County, California

Dear Mrs. Thompson:

An investigation of possible surface faults in the vicinity of the proposed Class I injection wells (project site) for the planned Elk Hills Power Plant was conducted in January and February 2000. The proposed injection well sites are located in Section 18, Township 31 South, Range 24 East, Mount Diablo Baseline and Meridian, Kern County, California. The project site is located on the southern margin of the Elk Hills oil and gas field.

PURPOSE AND SCOPE

Faults showing possible surface expression in the vicinity of the project site were mapped by William Lettis & Associates, Inc. (WLA). Details of the investigation conducted by WLA were documented in a report dated November 16, 1999 (Bachhuber and Brankman, 1999). Smith-Gutcher and Associates, Inc. was contracted by San Joaquin Energy Consultants, Inc. (SJEC) to provide an independent review of the WLA report with the focus limited to the possible faults mapped by WLA.

The area of investigation was limited to the region of possible faults mapped by Bachhuber and Brankman (1999). This area is about one mile (north-south) by six miles (east-west) along the south flank of Elk Hills. Bachhuber and Brankman (1999) described "...an apparent, east-west trending, continuous (4-mile long) fault in the Tulare Formation and younger alluvial fans (Pleistocene-Holocene) along the base of the Elk Hills immediately north of the [Elk Hills Power Plant] discharge well site..." The maps attached to the letter by Bachhuber and Brankman (1999) actually show two nearly parallel faults separated by about one-eighth of a mile along the base of the hills. Bachhuber and Brankman (1999) refer to one or both of these possible faults as the "south margin" fault. For discussion, these two possible faults will be referred to as the "south margin faults."

Existing geologic data were reviewed in varying degrees of detail. Geologic maps were carefully examined and the sections of reports dealing with geologic structure were studied in detail. Stereographic aerial photographs were examined under a Sokkisha MS-27 mirror stereoscope at zero magnification and at 3X magnification. Two days of field investigation, with the specific objective of locating the faults mapped by Bachhuber and Brankman (1999), were conducted. The entire investigation reported herein was conducted by Thomas F. Gutcher, Registered Geologist No. 5010.

REVIEW OF GEOLOGIC DATA

Three existing geologic maps were examined for evidence of the possible faults mapped by Bachhuber and Brankman (1999). The Geologic Map of California, Bakersfield Sheet (Smith, 1965) shows several northeast-southwest trending faults on the north flank of the Elk Hills anticline. None are shown on the south flank. No surface faults in the vicinity of the project site are shown on the Kern County Seismic Hazard Atlas (Kern County Council of Governments, 1974). The geology of the area covered by the Taft 15 minute topographic quadrangle was mapped by T. W. Dibblee, Jr. in 1966 and 1967 (Dibblee, 1971). No faults are shown on or near the project site. Dibblee's map shows several faults less than two miles long. One mapped fault is only about 1,000 feet long. This implies that two continuous, nearly parallel, four-mile long faults ("south margin faults") would be of sufficient size for inclusion on Dibblee's map if he had recognized the features mapped by Bachhuber and Brankman (1999) as faults.

The reports by Milliken (1992) and Bachhuber and Brankman (1999) were studied in detail because they are the most relevant to the issue of possible surface faults in the vicinity of the project site. A cursory review of the reports by Phillips (1992) and SJEC (1999) was conducted.

Milliken (1992) conducted a rather detailed geology and geohydrology investigation of a region immediately north of the project site. Detailed geologic mapping of the region, which covers an area about 3,000 feet (north-south) by one mile (east-west), was conducted by following bedding contacts in the field (Milliken, 1992). Milliken (1992) mapped Quaternary alluvium and seven units of the Tulare clay and plotted the data on a detailed topographic map with a contour interval of five feet to create a geologic map (Figure 6 in Milliken, 1992). Milliken's map shows the undulating appearance of the bedding contacts across the flank of the hills that is characteristic of dipping layers crossing gullies and ridges.

The region covered by Milliken's map includes portions of the "south margin faults" and another possible fault near the project site mapped by Bachhuber and Brankman (1999). Milliken (1992) did not map any faults in the region of coverage. To check for possible offset of the Tulare clay units mapped by Milliken (1992), the northernmost of the "south margin faults" was plotted on Figure 6 of Milliken (1992). The location of the possible fault trace was scaled off from the section line between Section 7 and 18 as shown on Figure 2 of Bachhuber and Brankman (1999) and transferred onto Milliken's map. Near the eastern edge of Milliken's study area, the possible fault trace, transferred as described above, cuts across the uppermost contact of the Tulare clay units. No offset is visible. The possible fault trace is parallel to and nearly coincident with the bedding contact over most of Milliken's map.

The approximate boundary of the study area of Milliken (1992) is shown on Figure 2 of Bachhuber and Brankman (1999). It appears that some of Milliken's map data was transferred onto Figure 2 of Bachhuber and Brankman (1999). However, there are some inconsistencies between the two maps. For example, the contact between the Tulare Formation and the Quaternary alluvium near the center of the boundary of Milliken's map extends in a v-shape northward into a gully. Milliken (1992) shows the next contact to the north, between two gravel beds of the Tulare clay (tg_1 and tg_2), with a slight v-shape to the south. This is the outcrop pattern of a bedding contact that dips in the same direction as the slope of the topography where the contact crosses a gully. In this same area, Figure 2 of Bachhuber and Brankman (1999) shows a contact between the Tulare Formation and the Tulare clay that follows the contact between the Tulare Formation and the Quaternary alluvium. That is, the contact extends in a v-shape northward into the gully. The outcrop pattern of the southerly dipping beds has to form a v-shape downslope (southward) where it crosses the gully.

It is noteworthy that Figure 2 of Bachhuber and Brankman (1999) shows the northernmost "south margin fault" crossing a contact within the Tulare Formation near the center of the boundary of Milliken's map. The possible fault trace cuts the bedding contact at about a 30° angle, but no offset of the contact is shown. If the "south flank fault" exhibits "...measurable strike slip and vertical throw..." as contended by Bachhuber and Brankman (1999), I would expect evidence of the offset to be clearly visible at this location.

Figure 8 of Milliken (1992) shows two possible faults roughly one mile north of the project site based on an interpretation of an "interesting fold in the Tulare Formation." One of these possible faults is shown intersecting the ground surface. None of the maps I examined show this possible fault (Dibblee, 1971; Kern County Council of Governments, 1974; Smith, 1965). Milliken (1992) offers an alternative explanation for the "interesting fold" that does not require faulting.

Milliken (1992) noted that, in his study area, the dip of the Tulare Formation steepens rapidly at the boundary between Section 7 and Section 18. Bachhuber and Brankman (1999) suggest that the steepening of the bedding may be attributed to fault movement. However, the cross section shown on Figure 7 of Milliken (1992) shows a normal increase in dip as the distance from the axis of the anticline increases. Milliken (1992) noted that "dips increase toward the Buena Vista Valley synclinal basin." The steepest dip reported by Milliken (1992) is 27° in a gravel unit of the Tulare Formation. Local bedding variations, which are common in gravel deposits, may account, in part, for the relatively high dip angle.

Bachhuber and Brankman (1999) observed that a cross section, referred to as AFC Figure 5.4-5, shows "a distinct inflection or 'bend' in the Tulare [clay] below the proposed injection well field." This is the cross section of Figure 8 from Milliken (1992). Bachhuber and Brankman (1999) suggest that the apparent bend in the Tulare Formation observed on the cross section is attributable to tectonic stress and possible faulting. Milliken (1992) noted that dips "...appear to decrease significantly in Buena Vista Valley between wells 86WS-18G and 1B-20G (figure 8)." Because the Buena Vista Valley is a synclinal basin (Milliken, 1992) situated between two large anticlines (see Dibblee, 1971 or Kern County Council of Governments, 1974), a flattening of the dip towards the axis of the valley is not unusual.

Of much greater relevance is the bend in the cross section alignment at well 86WS-18G (Figure 8 in Milliken, 1992). Between wells 88WD-7G and 86WS-18G, the cross section line is nearly straight and is oriented approximately north-south which is roughly parallel to the dip direction. A cross section line that is parallel to the dip direction shows bedding at the true dip. Any cross section line not parallel to the dip direction will show the apparent dip of the bedding, which is always less than the true dip. Thus, this portion of the cross section shows an apparent dip of the bedding that is fairly close to, but somewhat less than, the true dip. At well 86WS-18G, the cross section alignment bends to the southeast at about 45°. Between wells 86WS-18G and 1B-20G, the cross section line is oriented northwest-southeast and, therefore, is roughly parallel to the strike of the bedding. Thus, this portion of the cross section shows an apparent dip of the bedding that is much less than the true dip. The greater the angle between a cross section line and the dip direction, the flatter the bedding will appear. If a cross section line is parallel to the strike of the bedding, any dipping bed will appear to be flat. That is, it will have an apparent dip of zero.

A smaller bend in the cross section alignment also occurs at well 88WD-7G (Figure 8 in Milliken, 1992) where the cross section alignment bends slightly to the northwest. Between wells 62-7G and 88WD-7G, the angle between the cross section line and the dip direction is somewhat greater than between 88WD-7G and 86WS-18G. The cross section shows a noticeable decrease in the apparent dip of the bedding north of well 86WD-7G (Figure 8 in Milliken, 1992), some of which is caused by the bend in the cross section.

The 5.5:1 vertical exaggeration of the cross section (Figure 8 in Milliken, 1992) magnifies the apparent dip changes induced by the bends in the cross section line. Much of the change in the apparent dip shown on the cross section at wells 88WD-7G and 86WS-18G is caused by changes in the cross section geometry. There is no obvious structural component to the large apparent dip change shown at well 86WS-18G. The bedding would be more accurately shown with abrupt angular changes at wells 88WD-7G and 86WS-18G rather than the smoothed-out curves on Figure 8 in Milliken (1992).

A structure contour map on the base of the Tulare clay (Figure 9 in Milliken, 1992) that includes the area of the project site shows bedding attitudes that seem consistent with the cross section on Figure 8 in Milliken (1992). No faults are shown on the structure contour map. Multiple control points are shown both north and south of the "south margin faults." Milliken shows a possible significant decrease in dip south of well 86WS-18G on the structure contour map. However, no control points are shown south of well 86WS-18G to indicate the change in dip. The map (Figure 9 in Milliken, 1992) indicates that well 86WS-18G is near the transition from an anticline to a syncline that trends to the east-southeast at the southeast corner of the map. Most of the syncline is east-southeast of the map boundary beneath the Buena Vista Valley. This syncline is consistent with the structure shown on Dibblee (1971) and Kern County Council of Governments (1974). Buena Vista Valley is situated between two large anticlines separated by a syncline beneath the valley.

My review of the geologic data revealed no evidence, either direct or indirect, that supports the existence of the possible faults mapped by Bachhuber and Brankman (1999) except for the observations in the WLA report. It appears that Milliken has conducted the most detailed field investigation of the area that includes the three possible faults mapped by Bachhuber and Brankman (1999) that are nearest the project site. Milliken (1992) wrote "No evidence for faulting was observed within the study area."

FIELD INVESTIGATION

Two full days of field investigation were conducted in January 2000. The first day covered the area north and east of the project site. The second day covered the area west of the project site. All but the most distant possible faults mapped by Bachhuber and Brankman (1999) were investigated. Where practical, the possible fault traces were investigated on foot, both closeup and from higher vantage points. For discussion, nine of the specific possible fault segments mapped by Bachhuber and Brankman (1999) that I investigated are labeled with an identifying number shown on the attached map. The numbered possible fault segments, as shown on Figure 1 of Bachhuber and Brankman (1999), were dashed onto my aerial photographs for review. Although I did not include every possible fault segment mapped by Bachhuber and Brankman (1999) in the detailed discussion below, all but the most distant of the possible faults segments were studied.

Four pairs of stereographic aerial photographs were examined using a mirror stereoscope. The specific photographs are listed in the references. Photographic prints were made from the original negatives on file at the Kern County Public Works building to obtain the best photograph quality. Many sets of aerial photographs taken during different years are available from the County. I have seen all of the photograph sets numerous times. The 1975 aerial photographs were chosen for this investigation because the photograph image quality and stereographic effect are excellent. Also, the relatively large scale of the photographs is very consistent over the entire image. The 1975 photographs were shot with an intended scale of 1:12,000. The actual photographs deviate very little from this scale, even near the edges.

Possible Fault Segment 1

Possible Fault Segment 1 is located along the south flank of a small anticlinal hill west of the project site (Attachment 1). It is shown curving around the nose of the anticline and possibly connecting to the "south margin fault" to the east. Most of the possible fault appears to be mapped along bedding contacts that have a distinct topographic expression caused by differential erosion of units of varying resistance. No offset gullies or ridges are noticeable. Several linear features that are essentially parallel to and just south of the possible fault are visible on the photographs. These almost perfectly straight lines probably are pipelines; they are clearly manmade. One of the lines curves to the northeast around the nose of the anticline. Its position is nearly coincident with the possible fault. I did not observe any evidence of Possible Fault Segment 1, both in the field or on the aerial photographs, that I attribute to faulting.

Possible Fault Segment 2

Possible Fault Segment 2 is located just north and east of the small anticlinal hill west of the project site (Attachment 1). At the west end, it is shown along the southern edge of a stream channel next to the anticline. Near the nose of the anticline, it makes a slight jog to the north across the channel and then bends back to the south where it merges with a slight topographic depression crossing dissected deposits mapped by Bachhuber and Brankman (1999) as "old alluvial fan." Possible Fault Segment 2 was mapped by Bachhuber and Brankman (1999) as the western end of the "south margin fault."

If the eastern end of this possible fault segment is projected to the northwest without the jog, it lines up with linear features just north of the stream channel. The overall alignment thus formed is parallel to the bedding in the small anticlinal hill as well as the bedding just north of the project site. It also is aligned with the axis of a syncline mapped by Dibblee (1971). This may indicate the topographic expression of bedding in the Tulare Formation beneath the deposits mapped by Bachhuber and Brankman (1999) as "old alluvial fan." Considering the proximity of the Tulare Formation outcrops, the "old alluvial fan" deposits are likely to be a thin layer over the Tulare Formation.

No offset gullies or ridges are noticeable along Possible Fault Segment 2. This is readily observed where the possible fault crosses the dissected deposits mapped by Bachhuber and Brankman (1999) as "old alluvial fan." Just south and northwest of the possible fault, several linear features that are essentially parallel to the possible fault are visible on the photographs. These almost perfectly straight lines probably are pipelines and/or dirt roads. A dirt road observed in the field appeared to be located on or near the western end of the possible fault. The dirt road ended at essentially the same point as the possible fault segment. I did not observe any evidence of Possible Fault Segment 2, both in the field or on the aerial photographs, that I attribute to faulting..

Possible Fault Segment 3

Possible Fault Segment 3 is located just east of the nose of the small anticlinal hill (Attachment 1). At the west end, it is aligned with the projection of Possible Fault Segment 1, the ends being separated by an active ephemeral stream channel. The possible fault cuts across the "old alluvial fan" east of the small anticlinal hill and is shown connecting to the "south margin fault" to the east. On the aerial photographs, a topographic depression aligned with the possible fault is visible cutting across the "old alluvial fan." This feature was difficult to locate in the field, but I finally recognized it after noticing a steel monument mounted on a pipe. The monument indicated the location of an old oil well site near the western end the possible fault. Other evidence of an old well (wood blocks, rusted cables, etc.) also was observed around the monument. Looking east from the monument, I was able to see a faint depression. This was confirmed by viewing the area from near the top of the nose of the small anticlinal hill using the monument for reference. Evidence of the old well site appears to be visible on the aerial photographs as well.

The presence of the old well site along this topographic feature indicates a possible correlation between the well site and the topographic depression. A likely explanation is an old access road to the well site. Along the alignment of the possible fault, ridges and gullies on the west half of the "old alluvial fan" bend to the east, while those on the east half bend to the west or not at all. There is no consistent offset of the gullies and ridges along Possible Fault Segment 3. Again, there are many linear features crossing the "old alluvial fan" with orientations similar to the possible fault that are visible on the photographs. These almost perfectly straight lines probably are pipelines and/or dirt roads. The only evidence of Possible Fault Segment 3 that I observed, both in the field or on the aerial photographs, appears to be cultural. If the slight topographic depression were caused by a fault with measurable strike slip offset, as contended by Bachhuber and Brankman (1999), the offset of the gullies and ridges should be consistent, which clearly is not the case.

Possible Fault Segment 4

Possible Fault Segment 4 extends from the east end of Possible Fault Segment 2 across Recent alluvial deposits and just into the Tulare Formation north of the project site (Attachment 1). Possible Fault Segment 4 was mapped by Bachhuber and Brankman (1999) as part of the "south margin fault." Possible Fault Segment 4 appears to be simply a mapped connection between Possible Fault

Segment 2 and the eastern portions of the "south margin fault." I did not observe any evidence of Possible Fault Segment 4, both in the field or on the aerial photographs, that I attribute to faulting..

Possible Fault Segment 5

Possible Fault Segment 5 is oriented north-south and appears to be truncated by the "south margin fault" east of Possible Fault Segment 4 (Attachment 1). Figure 1 of Bachhuber and Brankman (1999) shows this possible fault ending at the northern boundary of a tank farm I will refer to as the "18G tank farm." Figure 2 of Bachhuber and Brankman (1999) shows this possible fault crossing the "south margin fault" with no offset. During the field investigation, I observed an aboveground pipeline that appeared to be coincident with Possible Fault Segment 5. This pipeline is not visible on the aerial photographs and must have been built after 1975. I suspect that this pipeline is visible on the aerial photographs used by Bachhuber and Brankman (1999) and that it was interpreted as a geologic structure. I did not observe any evidence of Possible Fault Segment 5, both in the field or on the aerial photographs, that I attribute to faulting.

Possible Fault Segment 6

Possible Fault Segment 6 trends east-west from the northeastern corner of the 18G tank farm for about one-half mile where the mapped extent ends at an ephemeral stream channel (Attachment 1). Observations in the field and on the aerial photographs indicate that most of this possible fault was mapped along a bedding contact within the Tulare clay. During a group field investigation on February 18, 1999, Bachhuber suggested that a drainage swale and ridge just east of the 18G tank farm was offset by this possible fault. Viewing the aerial photographs, several ridges to the east of the 18G tank farm do bend to the west somewhat at this alignment, indicating possible right-lateral offset. However, many other ridges bend the opposite direction. No consistent direction of offset is apparent.

An ephemeral stream channel bends to the west at the location that Bachhuber referred to in the field. However, a much larger ephemeral stream channel located to the west actually bends to the east at the same alignment as Possible Fault Segment 6. This is the same drainage that Possible Fault Segment 5 was mapped in. The bend in this channel is not visible on the photographs on Figure 1 of Bachhuber and Brankman (1999) because the area was covered by the development of the 18G tank farm. A levee constructed along the northern boundary of the 18G tank farm diverts the flow of this drainage to the east. Much of the evidence that there is no fault offset along the alignment of Possible Fault Segment 6 existed to the west of the possible fault segment. The evidence was altered during construction of the 18G tank farm. I did not observe any evidence of Possible Fault Segment 6, both in the field or on the aerial photographs, that I attribute to faulting.

Possible Fault Segment 7

Possible Fault Segment 7 trends east-west from near the northeastern corner of the 18G tank farm for about one-half mile (Attachment 1). The possible fault is parallel to Possible Fault Segment 6. Observations in the field indicated that this possible fault was mapped along a pipeline. In fact, over the entire length of Possible Fault Segment 7, it is exactly coincident with a pipeline visible on the 1975 aerial photographs. The pipeline even has same slight bend as Possible Fault Segment 7 (Attachment 1). I did not observe any evidence of Possible Fault Segment 7, both in the field or on the aerial photographs, that I attribute to faulting.

Possible Fault Segment 8

Possible Fault Segment 8 trends east-west from the northeastern end of Possible Fault Segment 6 for about one-half mile where the mapped extent ends at an ephemeral stream channel (Attachment 1). Observations in the field and on the aerial photographs indicate that most of this possible fault was mapped along bedding contacts within the Tulare clay. The mapped trace actually jumps slightly to the south from one bedding contact to another where the possible fault crosses an ephemeral stream channel. No offset gullies or ridges are noticeable. I did not observe any evidence of Possible Fault Segment 8, both in the field or on the aerial photographs, that I attribute to faulting.

Possible Fault Segment 9

Possible Fault Segment 9 trends east-west from near the eastern end of Possible Fault Segment 7 for about one-third of a mile (Attachment 1). The possible fault is parallel to the western end of Possible Fault Segment 8. Observations in the field indicated that this possible fault was mapped along the access road for an overhead utility line. The utility line appears to have been installed after 1975 as it is not visible on the 1975 aerial photographs. No offset gullies or ridges are noticeable. I did not observe any evidence of Possible Fault Segment 9, both in the field or on the aerial photographs, that I attribute to faulting.

CONCLUSIONS

Based on my review of the existing geologic data listed in the references, two days of field investigation, and an extensive review of aerial photographs, I do not believe there is any significant evidence of active surface faults in the vicinity of the project site. It appears that most of the possible fault segments were mapped along bedding contacts and cultural features. This investigation was conducted to the best of the investigative geologist's abilities using the data available at the time. If you have any questions or if we can be of further service, please feel free to call.

REGISTERED GEOLOGIST
THOMAS F. GUTCHER
No. 5010
STATE OF CALIFORNIA

Yours truly,

Thomas F. Gutcher
Registered Geologist
State of California No. 5010

TFG/tg

Attachment

REFERENCES

Bachhuber, J., and Brankman, C.M., 1999, letter dated November 16, 1999 to Lizanne Reynolds of Adams Broadwell Joseph & Cardozo, Attorneys at Law, regarding the proposed Elk Hills Power Plant project: William Lettis & Associates, Inc., 6 p. plus figures.

Dibblee, T.W., Jr., 1971, Geologic map of the Taft quadrangle, California: U.S. Geol. Survey Open File Map, geology mapped 1966 and 1967, geology drafted by G. Edmonston 1971, scale 1:62,500 (unpublished).

Kern County Council of Governments, 1974, Seismic hazard atlas, Taft quadrangle, Kern County, California, scale 1:24,000 (unpublished).

Milliken, M., 1992, Geology and geohydrology of the Tulare Formation, 7G/18G produced water disposal area, south flank NPR-1: United States Department of Energy, Naval Petroleum Reserves in California, Technical Report, December 1992, 22 p. (unpublished).

Phillips, M.V., 1992, Summary of Tulare Formation groundwater conditions along the south flank of Naval Petroleum Reserve No. 1, Elk Hills, Kern County, California: Research Management Consultants, Inc., December 1992, 17 p. (unpublished).

San Joaquin Energy Consultants, Inc., 1999, Information needs for class V injection wells, Elk Hills Power Plant, prepared for: Elk Hills Power, LLC, Elk Hills oil and gas field, Kern County, California, September 21, 1999: San Joaquin Energy Consultants, Inc., 27 p. plus attachments (unpublished).

Smith, A.R., 1965, Geologic map of California, Olaf P. Jenkins Edition, Bakersfield sheet: Calif. Div. Mines and Geol., fourth printing 1992, scale 1:250,000.

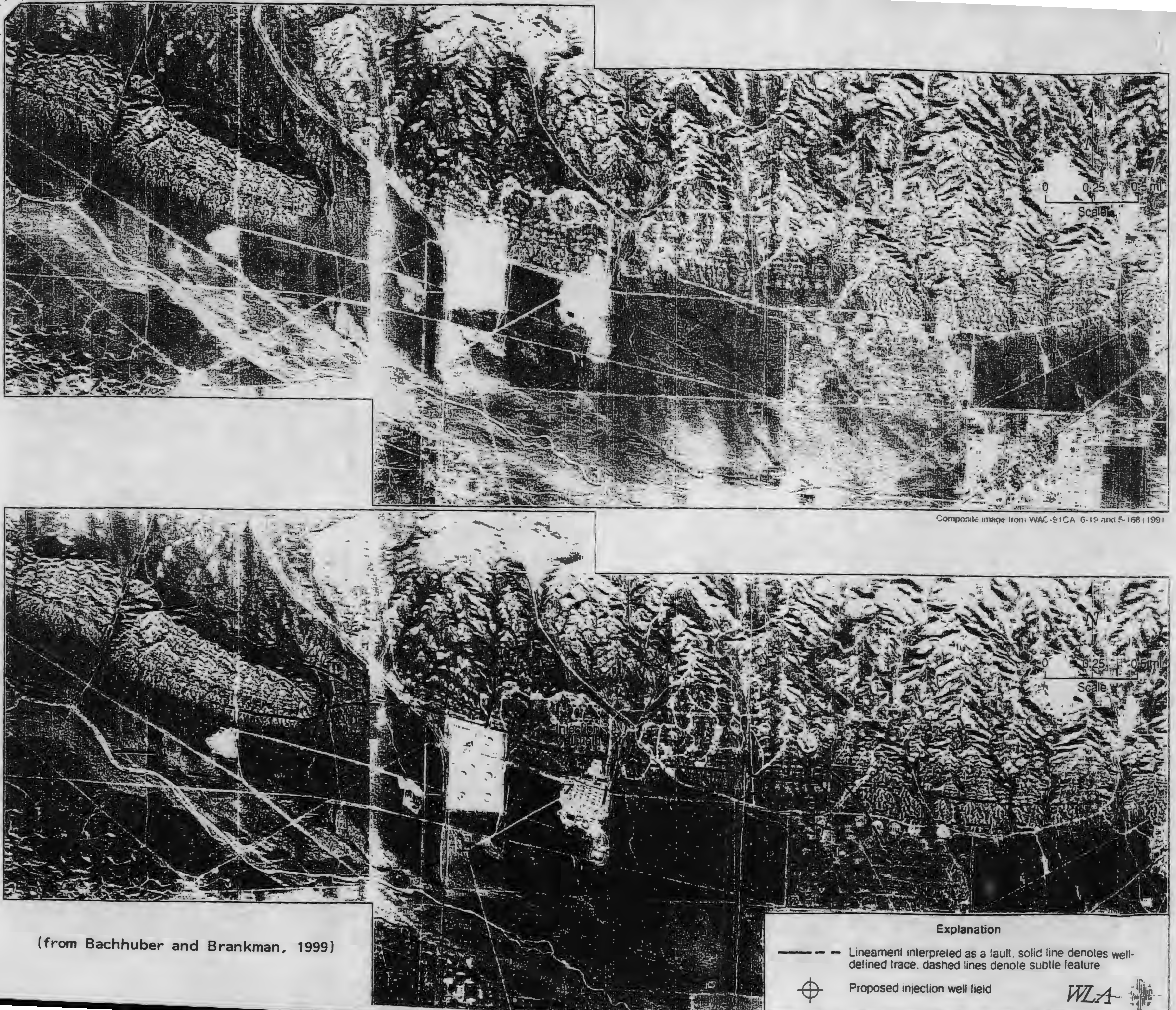
Aerial Photographs

Series 8M-832, numbers 3799 and 3800 (stereo pair), flown February 15, 1975, black and white, approximate scale 1:12,000.

Series 8M-832, numbers 3831 and 3832 (stereo pair), flown February 15, 1975, black and white, approximate scale 1:12,000.

Series 8M-832, numbers 3873 and 3874 (stereo pair), flown February 15, 1975, black and white, approximate scale 1:12,000.

Series 8M-832, numbers 3904 and 3905 (stereo pair), flown February 15, 1975, black and white, approximate scale 1:12,000.



(from Bachhuber and Brankman, 1999)

Figure 1. Aerial photograph showing faults in the proposed EHPP disposal well field area.

Attachment 1